NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

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SPECIFICATIONS FOR FILTERS FOR LOW LEVEL WHITE LIGHTING ON SUBMARINES

by

S. M. Luria and D. A. Kobus

Naval Medical Research and Development Command
Research Work Unit M0100.001-1023

Released by:

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SUMMARY PAGE

THE PROBLEM

To specify the density of neutral filters to produce low level white lighting aboard submarines to replace red or blue lighting.

THE FINDINGS

The background of the problem is outlined and the findings of the series of studies are presented. It is concluded that two sets of filters should be produced. For general use, filters should transmit 2.5 percent of the light (1.6 density). For lights which must remain on at all times and which would be distracting under rig-for-black, filters should be available which transmit 0.8 percent of the light (2.1 density).

APPLICATION

These recommendations are for the guidance of manufacturers producing filters for the submarine fleet.

ADMINISTRATIVE INFORMATION

This manuscript was submitted for review on 21 October 1986. Investigation was conducted under Research Work Unit entitled "Enhanced visual performance on submarines." It was approved for publication on 1 December 1986 and has been designated as NSMRL Memorandum Report 86-6.

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ABSTRACT

It has been proposed that the current practice of illuminating submarine compartments with red light at night be discontinued and that low level white light be substituted for the red and blue lighting. The background of the problem is presented briefly, and recommendations for the densities of the neutral filters are made.

Specifications for Filters for Low Level White Lighting on Submarines

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BACKGROUND

Red light has been used for many years to illuminate various submarine compartments at night, because dark adaptation is then achieved more quickly when the ambient light is turned off. This one advantage of red light is offset, however, by several disadvantages. The red light is fatiguing, it makes it impossible to read color-coded charts, and, indeed, it makes it more difficult to read anything. These problems have led to the desire to substitute another ambient light for the red lighting ~~(1)~~. A long series of studies has now shown that the problems associated with red light would be alleviated, if not eliminated, by substituting white light of generally comparable brightness. These results have previously been presented ~~(2,3)~~.

Briefly, laboratory studies have shown that, compared to red light, low level white ~~(LLW)~~ light does not degrade either contrast sensitivity ~~(4)~~, visibility through the periscope ~~(5)~~, detection of targets on sonar CRTs ~~(6-8)~~, or the ability to detect colored targets on CRTs ~~(9,10)~~. Nor is white light as fatiguing as red (11).

EVALUATIONS AT SEA

The laboratory studies were followed by a series of evaluations of the LLW at sea. The first ones were carried out in sonar compartments and resulted in favorable evaluations by the sonar crews (12). Evaluations were next carried out in the control room (13-17).

To compare the effectiveness of red and white light, it is first necessary to match them for brightness. With lights of low intensity-- as is the case with the dim red light used on submarines-- this cannot be done with photometers. These instruments are designed to be used only at normal day-time (photopic) levels of illumination.

Because the relative sensitivity of the eye to different colors changes at different intensities, equating different colors with a photometer at low intensities will not produce a brightness match for the eye (18). This must be done by an observer. Kinney (19) has published a nomogram which relates such brightness matches to photometric intensities. At the typical intensity level of the red light on submarines, a brightness match to the standard red filters (which transmits 10 percent of the light) is achieved with a neutral filter which transmits 5 percent of the light (density = 1.3).

The evaluations at sea of the LLW in the sonar compartments compared the red light-- or, in some cases, blue light-- with LLW produced with 1.3 density filters. The first evaluations at sea in the control room also used 1.3 density filters. These were rated as satisfactory by the crews of the first two submarines (13,14), but the crews in the next two evaluations rated the LLW as too bright (15,16). A second problem also arose. Kinney's nomogram was based on observations in which the judges looked directly at the lights. However, when the lights are seen out of the corner of the eye, the LLW appears to be too bright.

The reason for both problems is that there is a preponderance of day-time photoreceptors-- the cones-- in the center of the retina, whereas the periphery of the retina is populated almost exclusively by the night-time receptors-- the rods. The increase in sensitivity to white light compared to the sensitivity to red is more pronounced for the rods than the cones. Thus a brightness match between red and white which is mediated primarily by the cones (as would be the case for direct viewing) is not acceptable when viewed peripherally. A 1.3 neutral filter (transmittance 5%) was found to match the red filter when viewed directly; but when viewed peripherally, a 2.1 neutral filter (transmittance = 0.8%) was required to match the red.

The significance of this fact for the control room is that the brightness of peripheral lights (coming, for example, from the adjoining passageways or from the plotting tables) is acceptable when they are red, but it may be obtrusive and distracting when they are white.

The first problem was solved to the satisfaction of subsequent crews (15-17) by increasing the density of the neutral filters to 1.6 (2.5 percent transmittance). The second problem was solved by installing filters which transmitted only 0.8 percent of the light (2.1 density) over the lights which were judged to be distracting (17).

RECOMMENDED LLW FILTER DENSITY

On the basis of these studies, we recommend that neutral filters of two densities should be made available to replace the red and blue filters now in use.

For general installation, the filters should transmit 2.5 percent (1.6 density) of the light throughout the spectrum (± 0.5 percent). They should be manufactured in the form of sleeves which can be slipped over the two sizes of fluorescent tubes-- 2 feet long, 1.5 inch internal diameter; and 11.25 inches long, 0.6 inch internal diameter.

For installation over those lights which are too bright, a second set of filters should be available which transmit 0.8 percent (2.1 density) of the light (± 0.2 percent). The filters should be clearly marked as "light" and "dark" and the crews instructed in their use.

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